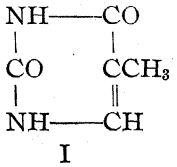
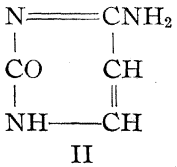
contain uracil. At least we found no evidence of its presence in the product which we investigated. We have succeeded, however, in isolating in a pure condition the two pyrimidines, thymine I and cytosine II.



I



II

Both pyrimidines were obtained in sufficient quantity for analysis and their constitution further established by the color reactions[1] characteristic of these two compounds, respectively. The two products isolated were compared with the pyrimidines obtained by synthesis and found to agree in every respect in chemical and physical properties. The further study of the chemistry of tubercle bacillus is in progress and the results of the investigation just finished will soon be published in The American Review of Tuberculosis and the Journal of Biological Chemistry.

[1] Wheeler and Johnson, *J. Biol. Chem.*, **3**, 1907 (183). Johnson and Baudisch, *J. Amer. Chem. Soc.*, **43**, 1921 (2670) and *Ber.*, **55**, 1921 (18).

THE RELATIVE SENSITIVITY OF THE EAR AT DIFFERENT LEVELS OF LOUDNESS

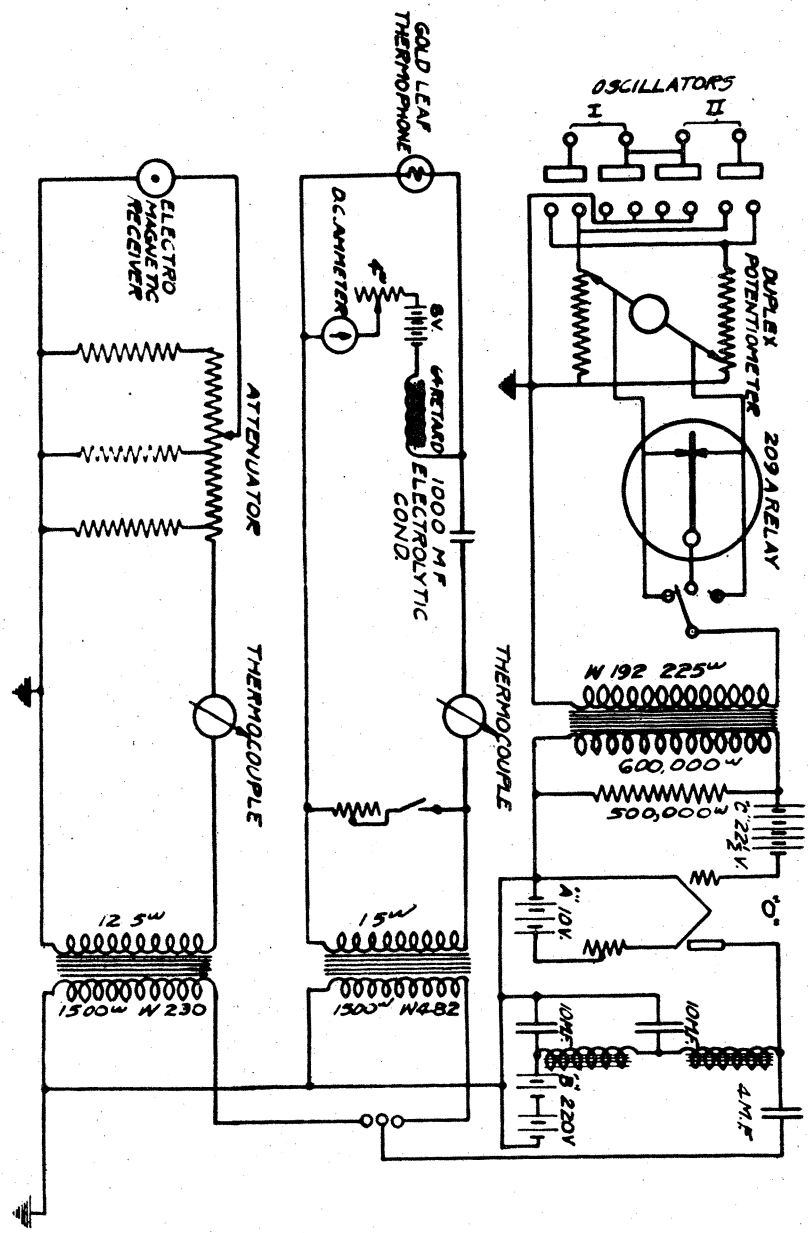
BY DONALD MACKENZIE

RESEARCH LABORATORIES OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY AND THE WESTERN ELECTRIC COMPANY, INCORPORATED

Read before the Academy, April 25, 1922

The threshold sensitivity of the ear for tones of various frequencies has been studied by many investigators. In order to determine the relative sensitivity at higher intensity levels, an alternation phonometer has been devised which permits balancing two tones of different frequency for equality of loudness.

The apparatus (fig. 1) consists of two vacuum tube oscillators, independently controlled, which through a relay commutator alternately supply current to a sound generator (either thermal or electromagnetic). The commutator is a polarized telegraph relay, driven at a suitable speed from another such relay. The commutating relay is adjusted to give a contact time of 1/25 second on each side, with a silent interval of 1/1000 second required for armature travel between contacts. This device differs in principle from the flicker photometer in that fluctuations in intensity are not caused to disappear and subjective fusion of the tones compared does not take place.* The interval (2/1000 second) through which auditory sensation persists after cessation of the physical stimulus



CIRCUIT OF THE ALTERNATION PHONOMETER

FIG 1

is so short that we cannot use the flicker principle as applied in photometry. Accordingly, the loudness balance is found when the flickers of the two tones are judged to be equally conspicuous.

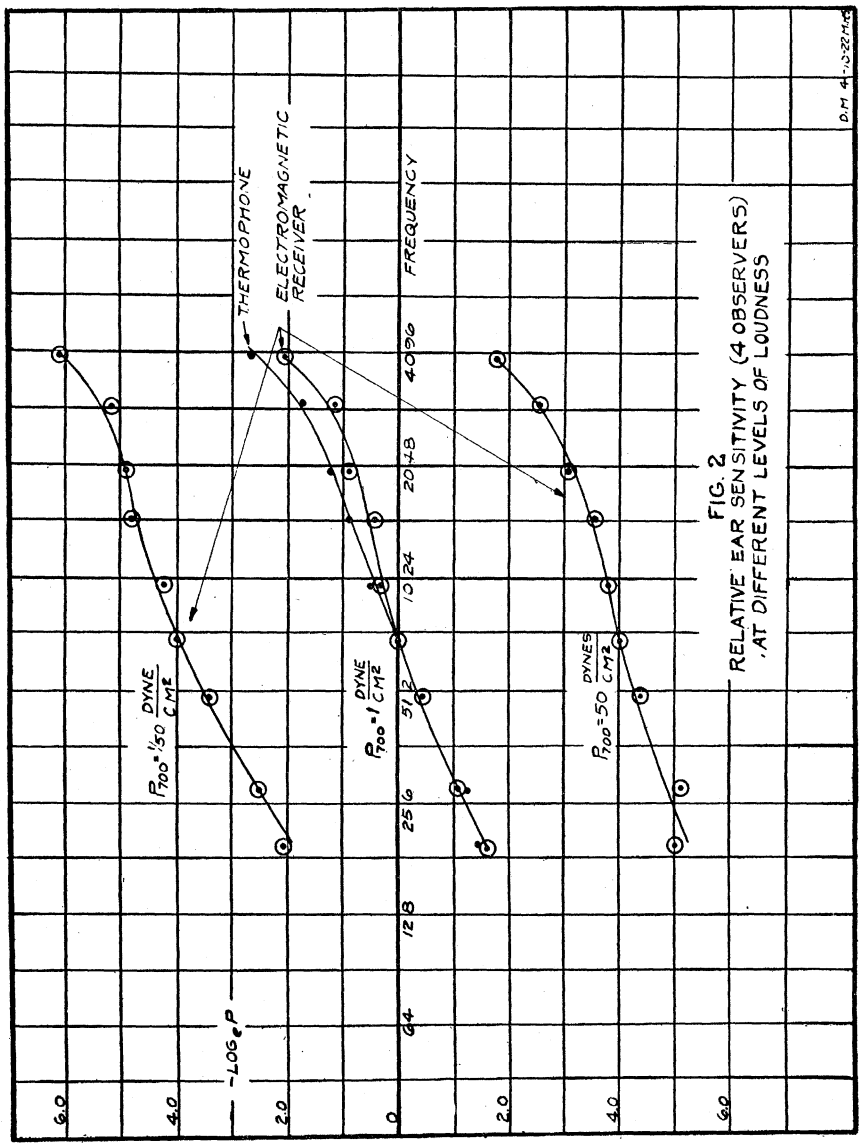


FIG. 2
RELATIVE EAR SENSITIVITY (4 OBSERVERS) AT DIFFERENT LEVELS OF LOUDNESS

It appears that this balance is definite. Balances can be repeated with an error of 5% or less; the tones so balanced are accepted by the ear as equally loud; two tones separately balanced against a third tone prove to be in balance with each other.

Twenty observers (ten men and ten women) using each one ear made observations with the thermal receiver over a range of frequencies from 100 to 4000 cycles per second, and in each comparison over a range of 10 to 1 in acoustic pressure. Their results are expressible in a simple logarithmic law: $\log P_1 = A + B \log P_2$, where P_1 and P_2 are the alternating pressures of two tones phonometrically balanced. This result is concordant with the simple formulation of Fechner's law.

The simple statement of Fechner's law holds only over the range of intensities throughout which the least perceptible stimulus increment is constant. Since the thermal receiver did not cover a wide range (the ear readily accomodates to acoustic pressures between 1/1000 and 1000 dynes per sq. cm.) the investigation was extended over wider limits of loudness, substituting an electromagnetic receiver as sound generator.

Only four observers took part in this work. Some consideration was devoted to the types of curves to be expected if the ear is presumed to resemble the eye in its variation in response to varying values of the stimulus. The expectation was that two types of curves showing the relation between the alternating pressures of the two tones compared would be met with; sensibly straight throughout, and curved in a specific way.

Tones of the following frequencies were compared directly with the 700 cycle tone: 200, 300, 500, 1000, 1500, 2000, 3000 and 4000 cycles. At levels of loudness from 1 to 10 napiers above the threshold (one napier corresponds to a pressure ratio of e to 1) phonometric comparisons were satisfactorily made. The results were as anticipated: of 32 curves, 25 were sensibly straight with slope unity over the whole range, 7 were curved oppositely in upper and lower halves.

The acoustic output of the receiver when held against the ear cannot be directly measured. Systematic errors, therefore, affect the receiver calibration obtained under artificial conditions. Nevertheless, these errors are the same at all intensities, and the predominance of straight phonometric lines of unit slope is evidence for the conclusion that the relative sensitivity of the ear is practically invariable over the range from near the threshold to near the level of painful loudness.

The individual differences among observers are smaller at intermediate levels than at the threshold, and no significant difference is found between the ears of men and those of women. Fig. 2 exhibits the relative ear sensitivity derived from the observations of 4 observers using the thermal and the electromagnetic receivers.

* A flicker phonometer similar in principle to the flicker photometer has been patented by C. M. Heck: U. S. Pat. No. 1,356,359; Oct. 19, 1920 "Method and Apparatus for for Comparing Sounds."